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WATER QUALITY AND POLLUTION CONTROL STUDY PATUXENT RIVER BASIN

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PRIORITIES

Patuxent River Basin

Waste Treatment

Location	Responsibility	Need	Priority
Laurel-Parkway Treatment Plant	Washington Suburban Sanitary Commission	Increase capacity and achieve 94 per cent 5-day BOD removal	A
Savage Treatment Plant	Howard County	Increase capacity and achieve 94 per cent 5-day BOD removal	A
Maryland City Treatment Plant	Anne Arundel County	Increase capacity and achieve 94 per cent 5-day BOD removal	A
Patuxent Treatment Plant	Anne Arundel County	Increase capacity and achieve 94 per cent 5-day BOD removal	A
Western Branch Treatment Plant	Washington Suburban Sanitary Commission	94 per cent 5-day BOD removal	A

Flow Regulation

Location	Responsibility	Need	Priority
Rocky Gorge and Triadelphia Reservoirs	Washington Suburban Sanitary Commission and State of Maryland	A minimum flow of 20 cfs for water quality control	A

Special Studies

Location	Responsibility	Need	Priority
Patuxent River Estuary	FWPCA, State of Maryland and PEPCO	Determine the extent and long-term effect of thermal pollution from PEPCO's Chalk Point Plant on the aquatic life in the Patuxent River Estuary	A
Basin-wide	FWPCA and State of Maryland	Determine the current nutrient level and establish removal required	A
Western Branch Treatment Plant	Washington Suburban Sanitary Commission, FWPCA, and State of Maryland	Determine the effect of the proposed treatment plant on the Patuxent Estuary	A
Tridelphia and Rocky Gorge Reservoirs	Washington Suburban Sanitary Commission and State of Maryland	Determine the feasibility and cost of low flow augmentation from the reservoirs	A

Institutional Practices

Location	Responsibility	Need	Priority
Basin-wide	State of Maryland and Local Governments	Consider establishing a centralized pollution control authority for the Basin	A
Basin-wide	State of Maryland and Local Governments	Develop a comprehensive pollution control plan	A

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I. INTRODUCTION

A. Purpose and Scope

The purpose of this report is to direct attention to existing and potential water pollution problems in the Patuxent River Basin.

Insofar as applicable, priorities for actions to achieve immediate pollution control needs will be presented with the specific objectives to:

1. Identify present and potential water quality problem areas.
2. Indicate responsibility for the problems.
3. Suggest immediate actions and responsibilities to alleviate the problems.
4. Estimate costs of these actions.

This report, by describing the immediate needs for controling water pollution in the Patuxent River Basin, represents the first step in the development of a comprehensive program to control water pollution in the Basin.

B. Authority

The basis for action can be found in the Federal Water Pollution Control Act (PL 84-660) as amended in 1961 (PL 87-88), the Water Quality Act of 1965 (PL 89-234), and the Clean Water Restoration Act of 1966 (PL 89-753), with special emphasis upon provisions regarding Comprehensive Programs for Water Pollution

Control, Grants for Water Pollution Control Programs, Grants for Construction, and Enforcement Measures against Pollution of Interstate or Navigable Waters.

C. Acknowledgments

The assistance and cooperation of various governmental and institutional agencies enabled the Chesapeake Field Station to assemble and evaluate water quality data in the Basin in what would otherwise have taken a much longer period. While every agency contacted provided valuable assistance, the cooperation of operating personnel at the Patuxent River Basin Sewage Treatment Plants and the following Government agencies and institutions merit special recognition:

Maryland Department of Water Resources

Maryland State Department of Health

University of Maryland Natural Resources Institute

Anne Arundel County Department of Public Works

Howard County Metropolitan Commission

Washington Suburban Sanitary Commission

U. S. Geological Survey, Department of the Interior

Fort Meade, Department of the Army

II. SUMMARY

A. General

In relation to other east coast basins, the Patuxent River Basin is unique in that there has been little or no historical urban development. Water quality problems can be related to past agricultural exploitation of the land; the diversion of upstream flows for water supply purposes; and, currently, the rapid suburban development, especially in the central basin area.

The accelerating population increase (255 per cent between 1940 and 1960) was the result of growth of the metropolitan areas of Baltimore and Washington and the expansion of area Federal facilities including Fort Meade, the National Agricultural Research Center, and the Goddard Space Flight Center. As the displacement of agriculture by suburban development continued, additional water supply and sewage treatment facilities were provided. Approximately ten million gallons per day (mgd) of fresh water and five mgd for developing industry are obtained primarily from surface water in the Basin. In addition, 40 mgd are diverted for use outside the Basin in the Washington Metropolitan Area by the Washington Suburban Sanitary Commission.

The water quality in the Patuxent River Basin has deteriorated as a result of increasing volumes of treated waste discharges and diversion of natural flows for water supply outside the Basin. The population projection for 1980 is 270,000, an

increase of 200 per cent over the 1960 population of 135,000. The projection of treated organic waste discharges shows an increase of 410 per cent from the present 7 mgd to the 1980 figure of 29 mgd, primarily in the Western Branch and in the upper Little Patuxent Sub-Basins.

Waste treatment requirements, based upon uniform treatment policy for projected 1980 loads, a minimum dissolved oxygen (DO) content in the stream of 5.0 mg/l, and for the 5 percentile of the mean monthly flow, were determined to be 94 per cent removal of 5-day biochemical oxygen demand (BOD). The effect of regulation of stream flow by discharges from Rocky Gorge and Tridelphia Reservoirs with a total storage capacity of 13.8 billion gallons was investigated. These Reservoirs, owned and operated by the Washington Suburban Sanitary Commission primarily for water supply, should supplement the proposed waste treatment standard of 94 per cent BOD removal with a 20 cfs flow to maintain the DO level. Increasing released water to 30 cfs would have no measurable effect in reducing treatment requirements. Based upon historical and synthetic hydrological evaluations of stream flow data, it was found that this multi-purpose use of the reservoir system could be maintained with a prospective failure incidence of only about five months in every 100 years.

Water quality in the River and Estuary has been monitored by the Maryland Department of Water Resources since 1961; the Natural Resources Institute is currently studying the effects of thermal discharges from the PEPCO Plant in the Estuary; with the U. S. Geological Survey participating and maintaining five robot monitors.

Tentative water quality standards have been proposed by the Maryland Department of Water Resources, and public hearings are currently being held, with plans for implementation and enforcement of the adopted standards scheduled in compliance with the Federal Water Pollution Control Act of 1965.

There are 24 significant waste water discharges in the Basin, with the largest organic loadings from the Laurel-Parkway, Bowie-Belair, and the two Fort Meade treatment plants. No major organic industrial waste water discharges occur in the Basin.

B. Immediate Pollution Control Needs

1. Waste Treatment

In order to accommodate the increased organic pollution load expected to occur in the Basin in the near future, the capacity and efficiency of existing treatment plants must be expanded. Also, a new treatment plant on the Western Branch will be required. To maintain a dissolved oxygen objective of 5 mg/l in the Patuxent River in the immediate future (1980), organic waste discharges must receive at least 94 per cent 5-day

BOD removal. The required increased capacity and the approximate cost of obtaining this degree of BOD removal are presented in the following table.

Treatment Plant	Required Added Capacity (mgd)	Cost
Laurel-Parkway	2.4	$2,264,000
Savage	7.0	$7,840,000
Maryland City	0.75	$1,223,000
Patuxent Plant	2.2	$3,796,000
Western Branch	5.0	$3,857,000
	17.35	$19,000,000

To aid in the reduction of the coliform counts in all waters of the Basin, organic waste effluents should be chlorinated continuously.

2. Flow Regulation

The additional treatment recommended in the foregoing will not achieve the immediate water quality goals in the Patuxent River (5 ppm DO) unless at least the five per cent minimum low flow is maintained in the River at all times. This flow could be achieved by releasing a minimum of 20 cfs from the Rocky Gorge and Tridelphia Reservoirs at all times. Rocky Gorge and Tridelphia Reservoirs are a part of the Washington Suburban Sanitary Commission's system which supplies water to parts of

the Metropolitan Area of Washington, D. C. Based on 1966 withdrawal rates from these Reservoirs, preliminary calculations indicate that 20 cfs could be released from the Reservoirs more than 99 per cent of the time without jeopardizing Washington Suburban Sanitary Commission water supply withdrawals. No costs have been established for this flow augmentation, but means for its accomplishment should be investigated, and the required releases negotiated.

3. Special Studies

Listed below are the areas in which a need for special studies is indicated.

Location	Responsibility	Need
PEPCO Chalk Point Plant	FWPCA, State of Maryland, and PEPCO	Determine the extent and long-range effect of thermal pollution from PEPCO's Chalk Point Generating Plant on aquatic life in the Patuxent Estuary.
Basin-wide	FWPCA and State of Maryland	Determine the current nutrient levels and establish the removal required.
Western Branch Treatment Plant	WSSC, FWPCA, and State of Maryland	Determine the effect of the effluent from the proposed treatment plant on the Patuxent Estuary.
Tridelphia and Rocky Gorge Reservoirs	WSSC and State of Maryland	Determine the feasibility and cost of low flow augmentation releases from the Reservoirs.

4. Institutional Practices

A centralized authority should be considered, and a comprehensive plan developed to achieve an orderly and integrated program for maintaining acceptable water quality in the Patuxent River Basin. Since the Patuxent River Basin is entirely within the State of Maryland, the responsibility for such an authority would be that of State and local governments.

C. Recent Pollution Control Progress

Plans for providing basin-wide water quality control have been initiated by various State and local institutions in the past. The principal ones are discussed below:

1. A regional sewerage plan, prepared by Wolman, Geyer, and Beavin, was submitted to the Maryland State Department of Health in 1960. Although the plan was never adopted, it has served as a guide for planning agencies.
2. The State of Maryland enacted the Patuxent River Watershed Act in 1961 to regulate erosion, floods, and urban development.
3. The State amended the Annotated Code of Maryland in 1966 to require counties to submit by 1970 comprehensive plans for water supply and sewerage systems to meet State and Federal standards. These are currently in preparation. The State Department of

Health has been given the authority to establish minimum requirements subject to review by the State Department of Water Resources.

Although the Patuxent River Basin is entirely within the State of Maryland, the River downstream from Hardesty is subject to tidal action; and this portion of the River is classified as a coastal or interstate stream. In compliance with the Federal Water Quality Act of 1965, the State is currently in the process of establishing water quality standards for interstate streams in Maryland. Also, the State is developing a plan for the implementation and enforcement of the standards.

III. DESCRIPTION OF THE STUDY AREA

The Patuxent River originates in the Piedmont geological area in Howard and Montgomery Counties and flows southeasterly approximately 110 miles through the Coastal Plain to Chesapeake Bay, draining an area of 930 square miles. The Basin lies wholly in the State of Maryland, encompassing parts of five Counties. The Piedmont streams characteristically drain a rolling hill and valley area but become broader and more sluggish in the Coastal Plain, expanding frequently into swamps and marshland.

The lower River is a tidal estuary under tidal influence extending upstream as far as Hardesty, 56 miles from Chesapeake Bay. During periods of low flow, salinity has been found at Lyons Creek, some 43 miles upstream.

The two major tributaries of the Patuxent River are the Little Patuxent and Western Branch, with drainage areas of 160 and 110 square miles, respectively. The Middle Patuxent, a tributary of the Little Patuxent, has a drainage area of 57 square miles.

The Patuxent River Basin receives an average of 44 inches of precipitation annually, with a resulting surface run-off of about 16 inches. Average annual temperature is 55° F., ranging from 0° to 100° F.

Since the days of the early settlers, land use in the Patuxent River Basin has been predominately agricultural over

the 930 square mile drainage area. Tobacco was grown on the Coastal Plain and remains a major crop, but the cereal grain crops raised in the Piedmont Area have been displaced by dairying during the past hundred years. More recently the Central Basin Area on both sides of the "Fall Line" separating the Coastal Plain and Piedmont Areas has become suburban, with economic bases for the most rapid population growth primarily in Baltimore, Washington, and in the Federal activities at Fort Meade and Beltsville.

Agriculture, however, remains the most important economic activity in the Basin, with a significant percentage of the southern Coastal Plain Area in tobacco, and dairying now the predominant activity in the northern Piedmont.

The sand and gravel deposits of the Coastal Plain are the only extensively used mineral resource of the Basin.

According to a survey made in 1953, land use in the Basin is as follows:

Forests	42 per cent
Fields and Meadows	43 per cent
Urban and Residential	15 per cent

When these data were compared to 1930 data, it was found that the percentage of forested land had remained static, while agricultural land had been lost to residential and urban use, a trend obviously continuing.

The 1960 population of 135,000 represented a 255 per cent increase over the 1940 figure of 53,000, with the most rapid growth in the Central Basin Area.

About 15 mgd of potable water are used for domestic and industrial purposes within the Basin, of which approximately two-thirds is domestic use and the remaining, industrial use. The major surface water withdrawals from the Patuxent Basin are as follows:

Utility	Quantity	Source
Washington Suburban Sanitary Commission	42.51 mgd	Patuxent (Rocky Gorge Reservoir)
Fort Meade	2.91 mgd	Little Patuxent River
Maryland House of Correction	0.82 mgd	Little Patuxent and Dorsey Run
PEPCO Chalk Point Plant	720.0 mgd	Patuxent Estuary for cooling water

The remaining water requirements are met from ground water sources and are estimated to be about 5 mgd[1]. About 40 mgd of the water are diverted to the Washington, D. C. Metropolitan Area for use outside the Basin.

There are 24 significant waste water discharges in the Basin, with the largest organic loading from the Laurel-Parkway, Bowie-Belair, and the two Fort Meade sewage treatment plants (Table 1). No major organic industrial waste water discharges occur in the Basin.

IV. EXISTING WATER QUALITY

Increase in waste water volumes, a high density of outfalls in limited areas, sluggish streams, and large diversions from the Basin for water supply combine to cause water quality problems in the Patuxent Basin. The degradation in water quality in reaches below the Fort Meade, Patuxent, Bowie-Belair, Laurel-Parkway, and Maryland House of Correction sewage treatment plant outfalls was very pronounced during the low flow periods of 1966.

The most significant waste discharges enter the Patuxent River in the Upper Basin above River Mile 45. To simplify investigation and presentation, the Upper Basin has been divided into three reaches and numbered as follows:

1. Main Stem of Patuxent from Mile 45.0 to confluence with Little Patuxent at Mile 63.70.
2. Main Stem of Patuxent from confluence with Little Patuxent to Mile 80.9 just below Rocky Gorge Reservoir.
3. Little Patuxent from confluence with the Patuxent to Savage at Mile 82.4.

The detailed field investigations and engineering studies necessary to evaluate the water quality in the Patuxent Estuary (downstream from River Mile 45) have not been performed at this time. Studies are being conducted, and the analysis of water quality in this portion of the Patuxent River will be reported at a later date.

As shown in Figure 1, the significant waste water discharges are found in reaches 2. and 3. Even though the majority of the waste is receiving at least 85 per cent treatment, there is a degradation in water quality in the reaches below Laurel and Fort Meade.

A. Biochemical Oxygen Demand and Dissolved Oxygen

During the low flow periods of July, August, and the early part of September 1966, the water quality in all three reaches near the confluence of the Patuxent and Little Patuxent Rivers was typified by DO values ranging from 1.0 to 4.0 mg/l and BOD's ranging from 4.0 to 22.0 mg/l. A summary of the water quality for selected stations is given in Table 2 and Table 3.

When the water quality is compared to that of 1961 for the same three months, it is apparent that it has deteriorated. Although waste water volumes have increased about 50 per cent in the past five years, some of the low quality can be attributed to the extremely low flows during 1966. For example, the mean monthly flow in August at Laurel was 5.73 cfs in 1966. The low flows that occurred during August 1966, based on a log normal probability relationship, have an occurrence probability of less than two per cent.

As presented in Tables 4 and 5, the quality data for the same selected stations in 1965 and 1966 indicate that the stream is reaching its maximum assimilative capacity. Due to large

differences in temperature in some of the sample data in 1965, a quantitative comparison cannot be made using 1965 data. However, data from both years indicate poor water quality in all reaches near the confluence with the Little Patuxent.

A major factor which indirectly affects the water quality, especially near the confluence with the Little Patuxent, is the large water loss due to evaporation, transpiration, leakage, etc. According to field measurements by the U. S. Geological Survey in 1966, there was about an 8 to 10 cfs loss of flow in the Patuxent between Laurel and the confluence with the Little Patuxent.

In the Patuxent the low flows have a twofold effect on the water quality:

1. The velocity of the stream is much less at low flows, thus, there is a larger exertion of BOD on the reaches just below the Laurel-Parkway, Bowie-Belair, and Patuxent treatment plant outfalls.
2. The low velocities reduce the reaeration rate of the stream, thereby the assimilative capacity of the stream is drastically reduced. For example, on August 8, 1966, the velocity of the Patuxent River near Bowie was calculated to be 0.2 fps, and reaeration coefficient was determined to be about 0.2 (base 10).

The high water loss rate from marshy areas of the Patuxent and small water releases from Rocky Gorge Reservoir (average of 5.73

cfs for August 1966) caused very sluggish flows in the Patuxent from Laurel to the confluence with the Little Patuxent River. In the Little Patuxent, the 6.0 mgd water withdrawal by Fort Meade and the Maryland House of Correction also significantly reduced the volume of dilution water during the low flow months.

B. Nutrients

A summary of nutrient data since 1961 from the U. S. Geological Survey and Maryland Department of Water Resources for select stations in the Patuxent River is presented below:

Location	Stream	River Mile	PO_4 as P (mg/l)	NO_3 as N (mg/l)
Laurel	Patuxent River	80.90	0.006	0.540
Fort Meade	Little Patuxent River	75.62	0.330*	0.535
Hardesty	Patuxent River	49.68	0.062	0.760
Lower Marlboro	Patuxent Estuary	30.65	0.061	0.576

* Average of two samples

From the summary it can be seen that the nutrient levels in the Basin are low. There are no reported algal problems in the Patuxent River.

C. Bacteriological Quality

As summarized in Table 3, high coliform counts are indicative of the water quality in the upper watershed. The high

counts are associated with agricultural land usage, sewage outfalls, and population centers.

The lower counts at Station 10 indicate a rather high die-away rate as one moves downstream; however, the bacterial quality of the Patuxent at Mile 42.0 is poor. This quality degradation is probably due to Western Branch, which also has a rather high coliform count.

D. Dissolved Solids

According to a study by the U. S. Geological Survey in 1962, the average dissolved solids concentration in the Patuxent River at Hardesty was determined to be 70 mg/l. The average daily load, which was computed to be about 73 tons, contains very small amounts of trace elements.

V. RECENT PROGRESS IN POLLUTION CONTROL

The local county governments have been responsible generally for zoning, land use planning, water supply, and waste disposal. In Howard County the initial sewerage plan was developed in 1958. The Washington Suburban Sanitary Commission has aided in water supply and waste disposal planning in Prince Georges and Montgomery Counties. For the remaining Counties in the Basin, sewerage planning was done on a community basis.

In 1958, officials from the interested Counties, State, and other planning agencies agreed to study the sewerage needs of the entire Patuxent Basin. The regional plan, which was developed by Wolman, Geyer, and Beavin, was completed in December 1960; and the recommendations are summarized below:

1. Construct, according to formulated schedule, sewerage treatment facilities at Laurel, Savage, Priest Bridge, and Mataponi Creek to serve the waste disposal needs of the Basin up to the year 2000.
2. Using low stream flows occurring less than five per cent of the time, with 23 cfs being released from Rocky Gorge Reservoir to maintain a minimum DO level of 5.0 mg/l, 90 per cent BOD removal was recommended for Mataponi Creek, Laurel, and Priest Bridge sewage treatment plants, while the Savage plant was to provide 92.5 per cent removal.

The regional plan, although never formally adopted, served as a guide for use by County and State planning agencies.

In 1961, the Maryland General Assembly enacted the Patuxent Watershed Act. According to this Act, a board of commissioners and representatives of the State Government was to coordinate County and State activities for:

> "...the purpose of protecting said watershed by a program of flood prevention, conservation, the protection of areas therein subject to sediment or erosion damages, and to prevent encroachment therein by the rapid spread and growth of urban development, and to cooperate with local, County, State, and Federal agencies; and it is hereby declared that such flood prevention, conservation, sediment or erosion protection, and the prevention of urban development within said watershed is a public benefit conducive to the public health, safety, and welfare." (2, Section 411A)

Attempts have been made recently to amend the Act in order to make it more effective in accomplishing its goals.

In 1966, the General Assembly amended the Annotated Code of the State of Maryland relating to water supply and sewerage. According to the amendment, the Counties are required to develop County plans to provide adequate water supply systems and sewerage systems by 1970 and to include a time schedule with cost figures to implement the program. The State Department of Health was designated the approving agency with opportunity for review offered to the Maryland Department of Water Resources.

Numerous studies have been conducted on various problems and conditions in the Patuxent Estuary. In order to determine the effect of the cooling water discharge from the proposed PEPCO Chalk Point Plant, a study was initiated by the Natural Resource Institute of University of Maryland, the U. S. Geological Survey, and the Chesapeake Bay Institute of The Johns Hopkins University. The power plant was placed in operation in 1964, and part of the study is being continued.

In January of 1966, the Governor of Maryland announced that the State of Maryland would comply with the Federal Water Quality Act of 1965. The State is currently establishing:

1. Water quality standards for interstate waters in Maryland.
2. A plan for the implementation and enforcement of the standards.

Public hearings are being conducted preliminary to the establishment of such standards and plan.

VI. IMMEDIATE WATER POLLUTION CONTROL NEEDS

In the design of a system for maintaining water of good quality in the Patuxent River Basin, the following must be considered:

1. The projected 410 per cent increase in municipal water discharges by 1980.
2. The high rate of diversion of the Patuxent River water by the Washington Suburban Sanitary Commission for water supply purposes.
3. The maximum use of assimilative capacity of the streams in conjunction with effective sewage treatment in order to maintain good water quality in the Patuxent Basin.
4. Possible transportation of waste water to the Estuary.
5. Nutrient removal.

The design of the system must also reflect possible trade-offs between low flow augmentations from the presently existing reservoirs and increased treatment requirements. The methods of analyses employed in this report are discussed in Appendix C.

A. Treatment Requirements

The various treatment levels which would be required to maintain a DO of 5 mg/l for the 1980 projected waste water volumes at various flow probabilities, if no reservoirs existed, are presented in the following table:

Mean Monthly Low Flow Probability	Treatment Requirements*		
Per Cent of Time	July	August	September
5	94	94	94
2	94	94	94
1	95	96	95

* Per cent BOD removal values rounded upward

The data in this table shows that, using the five per cent mean monthly low flow and a minimum DO requirement of 5.0 mg/l, all waste water should receive a minimum of 94 per cent BOD removal. In the determination, it was assumed that all the minimum DO's in the effluent were 4.0 mg/l, there was an 8.0 cfs loss in the marsh in the critical area, and there were no reservoirs in the system.

B. Flow Regulation

The effect of fixed release from the Rocky Gorge Reservoir on treatment requirements for the month of August is as follows:

Release Flow (cfs)	Treatment Requirements (Per Cent of BOD Removal)
5	96
10	95
15	95
20	94
30	94

Data in the above table were calculated assuming all other stream flows at the 5 percentile, a mean August stream temperature of 21.3° C, a DO minimum of 5.0 mg/l, and a uniform treatment policy were utilized in the calculations.

Based on a mean September stream temperature of 18.5° C, the effect of flow regulation on treatment requirements is as follows:

Release Flow (cfs)	Treatment Requirements (Per Cent of BOD Removal)
5	95
10	94
15	93
20	93
30	93

This table indicates that only slightly less treatment is required to achieve the objective of 5.0 mg/l for the month of September.

As indicated in the tabulation for August, a minimum of 20 cfs (which is the 5 per cent mean monthly low flow) should be released from Rocky Gorge Reservoir in conjunction with a minimum

treatment requirement of 94 per cent removal of BOD. Increasing the minimum release to 30 cfs has no measurable effect on waste water treatment requirements. Using Fiering's hydrology model, the 30 years of unregulated historical data, 1914 to 1944, were routed through the reservoir system. The Washington Suburban Sanitary Commission 1966 monthly withdrawal rate for water supply requirements was also read into the model (see Table 8). The number of months in which the indicated release flow was not met is given below:

Release Flow (cfs)	Number of Months Deficient
10	1
15	3
20	5
30	11
40	25

In reviewing the 30 years of unregulated stream flow data at the gage at Laurel, Maryland (formerly Burtonsville, Maryland), the mean monthly flow that occurred in 1931 has a recurrence interval of about once in 100 years. Therefore, the drought that occurred in the early 1930's probably has a minimum recurrence interval of once in 100 years.

Twenty 150-year periods of synthetically generated flows were routed through the reservoir system under the same conditions as above. The probability of not meeting the mean monthly release as indicated is given below:

Release Flow (cfs)	Probability of Monthly Failure (Per Cent)
10	less than 0.05
20	less than 0.05
30	0.20
40	1.20

Since increasing the release flow above 20 cfs will have little measurable effect on lowering the BOD removal requirements, nothing would be gained by requiring a release greater than 20 cfs. The failure rate for the 20 cfs release rate, based on specified treatment requirements, would be five months in 100 years, based on historical data, or less than 0.05 per cent of the time, based on the synthetically generated flow data. If the 20 cfs release rate is maintained, and all waste water is subjected to 94 per cent removal of BOD, both the 5.0 mg/l DO objective and the current water supply withdrawal rates of the Washington Suburban Sanitary Commission will be met greater than 99 per cent of the time.

C. System Cost

No cost estimates have been established for the requirement of releasing 20 cfs from the existing reservoir system, but the above analyses have indicated that it could be done with little change in the current water supply withdrawal rates. Means for accomplishing this release should be investigated, and the required release negotiated.

Each of the agencies has developed plans for meeting its projected waste water treatment requirements. The cost of the proposed expansion program is as shown in the following table:

Community	Added Capacity	Cost
Laurel-Parkway (WSSC)	2.4 mgd	$1,850,000
Savage (Howard County)	7.0 mgd	$6,400,000
Maryland City (Anne Arundel County)	0.75 mgd	$1,000,000
Patuxent Plant (Anne Arundel County)	2.2 mgd	$3,100,000
Western Branch (WSSC)	5.0 mgd	$3,150,000
		$15,500,000

The above costs, which include the secondary treatment facilities only, were obtained from various consulting engineers' reports, county plans, etc.[6,7,8,9,26]

In order to maintain the water quality criteria of 5.0 mg/l DO, 94 per cent removal of BOD for the projected 1980 waste water discharges is required. To aid in reducing the coliform counts in all waters of the Basin, all organic waste effluents must be chlorinated continuously. The cost of the increased BOD removal rate, according to a study by Frankel[25], from 85 per cent to 94 per cent is about 20 per cent of the basic plant cost for a 2.5 mgd plant and about 25 per cent for a 10 mgd plant.

Using an average cost increase of 22.5 per cent for a 4.0 mgd plant, the increased construction cost is estimated to be $19,000,000.

Other factors that must be considered in waste water treatment are nutrient removal requirements and cost. Nutrient removal requirements and cost were not determined because of insufficient data. However, using average nutrient loadings from ten sewage treatment plants in the Potomac River Basin and the limited stream sampling data available, it appears that the Patuxent River has a large capacity for assimilating phosphorus.

Expressing phosphorus removal by the sediments, aquatic plants, etc., by a first order reaction, it was estimated that the removal coefficient is about 0.30 (base 10). Until the mechanisms of removal and controling factors are firmly established and the resulting algal blooms documented, treatment requirements for phosphorus cannot be determined with precision. As indicated above, the required uniform treatment is 94 per cent removal. The type of treatment facility required to obtain this high BOD removal rate will affect the concentration of nutrients in the final effluent. Therefore, in the waste treatment plant design phase, consideration should be given to possible future nutrient removal requirements.

In lieu of formulating the nutrient removal requirements at the present time, a study should be initiated to determine

the current nutrient level and establish the rate of removal. Upon completion of this study, an evaluation of nutrient treatment requirements will be possible. (Preliminary studies are currently being conducted by the Chesapeake Field Station, CB-SRBP.)

D. Transportation to Estuary and Estuarine Consideration

In developing the Regional Sewerage Plan, Wolman, Geyer, and Beavin[6] investigated the possibility of disposing of all Basin sewage to the Patuxent Estuary by means of a continuous interceptor system leading to a single large treatment plant located near Mataponi Creek. Their investigations indicated that the Estuary was incapable of assimilating the effluent from a single point discharge.

Further investigation by Wolman, Geyer, and Beavin showed the feasibility of discharging the effluent to Chesapeake Bay, provided it is planned jointly with the District of Columbia Government for disposal of their final effluent. This plan for disposal into Chesapeake Bay by the District of Columbia has not been adopted.

The proposed Western Branch Sewage Treatment Plant by Washington Suburban Sanitary Commission, plus the projected increased stream load, will result in water quality deterioration in the Estuary. Due to the two-layer nature of the Patuxent

Estuary and currently indeterminate effects of the PEPCO Chalk Point Plant, the use of Thoman's estuary model or spectral analysis in conjunction with substantial field work will be required to fully evaluate the significance of this water quality deterioration. A study of this nature will also be valuable in assessing the effects of nutrients in the Patuxent Estuary.

APPENDIX A

SOURCE OF DATA

The basic population projections were obtained from the National Planning Association. Projections were also obtained from the Howard[8] and Anne Arundel[26] County water and sewerage master plans. The Regional Sewerage Plan Report by Wolman, Geyer, and Beavin[6] and the Patuxent Report by the Water Management Seminar of The Johns Hopkins University[10] were also sources of population projections and the dichotomy of population within the Basin.

Surface water discharge rates were obtained from the U. S. Geological Survey.[15,16,17] The U. S. Geological Survey has six permanent and six temporary gaging stations within the Basin.

Chemical and biological water quality data were obtained from the Maryland Department of Water Resources. This Department conducts a monthly sampling program at 34 stations within the Basin, some of which were established in 1961 and other stations added since 1962. The Department has also conducted surveys in the Estuary from 1962 to 1964. Intensive surveys were also made by the Department in the Upper Patuxent River during the summers of 1964, 1965, and 1966. Sampling stations for the Patuxent River are shown in Figure 2. Chemical quality water data were also obtained from the U. S. Geological Survey which

has established five stations for monitoring water quality in the Estuary.

Monthly operating reports were obtained from all major waste treatment plants within the Basin. Operational data for the remaining discharges were obtained from the Maryland Departments of Health and Water Resources.

Stream temperature data were obtained from the Fort Meade water treatment plant records in order to establish mean monthly water temperatures for the Patuxent River.

Time-of-travel and cross-section data were obtained by personnel of the Chesapeake Field Station, CB-SRBP. Dye studies were conducted by the U. S. Geological Survey in 1965 and were also used to establish time-of-travel.

APPENDIX B

FORMULATION PARAMETERS AND CRITERIA

1. Population and Waste Water Projections

In order to further define the water resources problems in the Basin, the immediate needs were expanded to include requirements up to the year 1980. The population projections of National Planning Association, as tabulated in Table 9, indicated that the Basin population will increase about 200 per cent by 1980. Projections by the various counties, planning agencies, and consulting engineering firms are somewhat higher; however, all projections indicate a rapid rate of growth in the Basin.

Due to the large projected increase in population, each of the major planning agencies within the Basin was contacted and, whenever possible, supplied projected waste water discharges for 1980. Since planning agencies are more familiar with the local sewage effluent problems, and only part of each County is within the Basin, the projected waste discharges obtained from planning agencies were used in the study. The current and projected flows from major sewage treatment facilities are given in Table 6.

2. Stream Flow

The design stream flow used in determining pollution control needs is the mean monthly low flow which occurs five per cent or less of the time (Table 7). The consecutive 7-day

low flow with recurrence interval of once in ten years, as recommended by the Maryland Department of Water Resources, is quite similar to the design flow (as can also be seen in Table 7). The advantage of using the mean monthly flows is that flow and temperature can be more realistically incorporated in prediction of water quality.

3. Water Quality

Since the parameter which is most indicative of water quality in a free-flowing stream is dissolved oxygen, the treatment requirements and/or flow requirements were determined using a minimum dissolved oxygen level of 5.0 mg/l.

In order to keep the waters essentially free from heavy growths of rooted plants, slimes, algae, and other plankton, the Sub-Task Force on Water Quality on Project Potomac has proposed a phosphorus maximum of 0.1 mg/l. This has been used in this report.

APPENDIX C

METHOD OF DATA ANALYSIS

A mathematical model relating temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), and stream flow was established for the Basin. Thomas' step method version[2] of the oxygen-sag equation is the basic algorithm in the model. The steady-state temperature formulation of Duttweiler[3] was employed as the temperature algorithm in the model. The reaeration coefficient for each section was calculated employing the Churchill formulation.[4]

For the model study, the Patuxent River Basin above Estuary River Mile 45.0 was divided into 28 physically-homogeneous sections (Figure 3). Logarithmic velocity versus stream flow and logarithmic depth versus stream flow relationships were developed for the 12 gaging stations. The relationships are as follows:

$$\text{Depth} = AA \times \text{Flow}^{BB}$$

$$\text{Velocity} = CC \times \text{Flow}^{DD}$$

The exponents were established at each of the gaging stations and extended to other sections within the model. The constants for the relationships were determined primarily by cross-sections and time-of-travel studies. Exponents and constants for each of the sections are tabulated in Table 10.

The model, which was programed on a digital computer, was verified by comparing the calculated results with known water quality conditions. The verification procedure used was as follows:

1. Establish the constants and exponents for the depth and velocity relationship for the sections.
2. From existing water quality data, determine deaeration coefficient.
3. Compare the calculated BOD profile with field results and, if necessary, adjust the deaeration coefficient.
4. Once the calculated BOD profiles were satisfactory, the calculated DO profiles are compared to field results.
5. When necessary, the depth constants are uniformly adjusted in order to yield a satisfactory DO profile.

Once the model was verified, it was used to predict the water quality at various treatment and discharge levels. A computed and a field data profile are shown in Figure 4. Water quality predictions were made for the months of July, August, and September in order to take into consideration low flow conditions and water temperatures simultaneously.

The following assumptions were made in projecting water quality.

1. All waste water discharges have a DO of 4.0 mg/l.

2. The temperature of all waste water discharge was 25° C.
3. The deaeration rates of the waste waters will be equal to those as determined in the verification procedure.
4. BOD in the waste discharges will remain relatively constant.

In order to determine how much water could be released for water quality control from Rocky Gorge Reservoir without jeopardizing the water supply needs of Washington Suburban Sanitary Commission, the synthetic hydrology model of Fiering[5] was used. The 1966 water supply figures were used in the model.

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TABLE 1

MUNICIPAL AND INDUSTRIAL WASTE WATER INVENTORY

Name	Employees or Population Served	Waste Type	Discharge Volume (mgd)	P. E. of Discharge	Per Cent Removal of BOD	Type of Treatment	Receiving Stream	Remarks
Maryland City STP	3,600	Sanitary	0.436	200	96	Secondary	Patuxent River	
Laurel-Parkway STP	25,000	Sanitary	2.00	2,100	85	Secondary	Patuxent River	Operated by WSSC
Bowie State Teachers College	460	Sanitary	0.050	5	95	Tertiary	Tributary to Horsepen Branch	
Bowie Race Track STP	Varies	Sanitary	0.125	Varies	50E*	Intermediate	Horsepen Branch	Seasonal Operation
Bowie-Belair STP	21,000	Sanitary	1.44	1,000	90	Tertiary	Tributary to Patuxent River	
Doughoregan Manor	52	Sanitary & Industrial	0.010	0	100	Secondary	Tributary to Little Patuxent	No Discharge
Donloggin STP	600	Sanitary	0.050	72E	85E	Secondary	Plume Tree	Will go to Savage STP
University of Maryland, Folly Quater Farm	21	Sanitary & Industrial	0.013	34E	85E	Secondary	Middle Patuxent River	
W. R. Grace Company	350	Sanitary & Industrial	0.052	95E	85E	Secondary	Middle Patuxent River	
Johns Hopkins Laboratory	2,000	Sanitary & Industrial	0.065	170E	83	Secondary	Middle Patuxent River	

TABLE 1 (Continued)

Name	Employees or Population Served	Waste Type	Discharge Volume (mgd)	P. E. of Discharge	Per Cent Removal of BOD	Type of Treatment	Receiving Stream	Remarks
Savage STP	700	Sanitary & Industrial	0.072	140E	85E	Secondary	Little Patuxent River	
Maryland and Virginia Milk Products	45	Industrial	0.150	280E	85E	Secondary	Hammond Branch	
Laurel Race Track	Varies	Sanitary	0.020	Varies	50E	Primary	Hammond Branch	Seasonal Operation
Maryland House of Correction	2,500	Sanitary	0.425	880E	85E	Secondary	Dorsey Run	
Fort Meade #1 STP	15,000	Sanitary	1.117	1,700	86	Secondary	Little Patuxent River	
Fort Meade #2 STP	30,000	Sanitary	0.938	1,400	93	Secondary	Little Patuxent River	Includes NSA, etc.
Naval Academy Dairy	100	Sanitary & Industrial	0.100	795E	35E	Primary	Towsen Run	
Patuxent STP	2,500	Sanitary	0.424	60	93	Secondary	Little Patuxent River	Operated by Anne Arundel County
Anne Arundel Sand and Gravel	N.A.	Silt	0.140	0	N.A.	N.A.	Little Patuxent River	
Bi County Sand and Gravel	N.A.	Silt	0.360	0	N.A.	N.A.	Patuxent River	
Annapolis Sand and Gravel	N.A.	Silt	0.384	0	N.A.	N.A.	Patuxent River	

TABLE 1 (Continued)

Name	Employees or Population Served	Waste Type	Discharge Volume (mgd)	P. E. of Discharge	Per Cent Removal of BOD	Type of Treatment	Receiving Stream	Remarks
Andrews Air Force Base	N.A.	Sanitary & Industrial	0.300	360	90	Secondary	Tributary to Cabin Run	
Upper Marlboro STP	700	Sanitary	0.060	300E	50E	Intermediate	Western Branch	
PEPCO Chalk Point Electric Plant	N.A.	Thermal	720.000	0	N.A.	N.A.	Patuxent Estuary	Put in operation in 1964.

* Estimated Values

N.A. = Not Applicable

TABLE 2

SUMMARY OF WATER QUALITY DATA FOR LOW FLOW PERIODS 1961 AND 1966

Station	River Mile	1961* No. of Samples	1961* Ave. Temp. (° C)	1961* Ave. DO (mg/l)	1961* Ave. BOD (mg/l)	1966** No. of Samples	1966** Ave. Temp. (° C)	1966** Ave. DO (mg/l)	1966** Ave. BOD (mg/l)
5	42.40	3	24.3	6.2	1.2	3	24.5	5.1	3.3
8	60.70	3	21.6	6.8	0.87	6	22.9	2.9	6.7
10	63.80	3	20.8	6.6	1.0	6	23.1	1.7	9.3
11	66.30	3	22.2	6.9	0.7	6	22.6	5.1	4.1
12	68.60	3	22.0	6.0	1.0	6	22.9	3.7	6.3
13	71.43	3	21.8	3.8	3.5	6	22.5	3.4	8.5
14	75.0	3	21.7	6.7	1.54	6	21.3	6.8	4.4
15	78.03	3	21.5	8.3	2.1	6	19.9	8.9	3.3
L1***	63.80	3	21.8	6.6	1.1	6	22.4	3.7	6.9
L2	66.80	3	22.7	6.7	1.3	3	22.1	4.5	7.6
L3	71.20	3	23.3	7.8	1.0	3	22.3	6.3	3.7
L4	74.05	3	23.7	7.8	1.4	3	22.7	4.5	4.6
L6	77.2	3	22.0	7.8	0.7	3	23.0	.2	4.2
L6A	Dorsey Run	3	18.3	5.9	4.5	3	21.3	3.2	11.5
L7	81.35	3	25.0	8.2	0.9	3	24.2	9.1	3.1
L8	85.2	3	22.7	8.6	0.5	3	22.0	9.2	3.2

* Average Flow = for the period during 1961
at Station 15 = 11.8 cfs
at Station L8 = 10.7 cfs

** Average Flow = for the period during 1966
at Station 15 = 6.3 cfs
at Station L8 = 5.1 cfs

*** L Prefix denotes Little Patuxent River

TABLE 3

SUMMARY OF BACTERIOLOGICAL DATA
FOR JULY, AUGUST, AND SEPTEMBER

Station	River Mile	Mean Coliform Count		
		July (MPN/100 ml)	August (MPN/100 ml)	September (MPN/100 ml)
5	42.40	120,000	14,000	18,000
8	60.70	41,000	22,000	11,000
10	63.80	8,000	1,600	5,000
11	66.30	8,000	1,800	4,000
12	68.60	43,000	1,900	8,000
13	71.43	11,000	1,600	1,500
14	75.0	81,000	170,000	529,800
15	78.03	52,000	36,000	73,000
L1*	63.80	12,000	24,000	1,800
L2	66.80	37,000	18,000	22,000
L3	71.20	7,000	18,000	24,000
L4	74.05	28,000	62,000	32,000
L6	77.20	98,000	62,000	141,000
L6A	Dorsey Run	53,000	18,000	24,000
L7	81.35	168,000	65,000	64,000
L8	85.20	21,000	26,000	23,000

* L Prefix denotes Little Patuxent River

TABLE 4

WATER QUALITY DATA FOR MONTHS OF
JULY, AUGUST, AND SEPTEMBER 1965

Patuxent River Basin

Station	River Mile	BOD min. mg/l	BOD ave. mg/l	BOD max. mg/l	DO min. mg/l	DO ave. mg/l	DO max. mg/l	TEMP. min. ° C	TEMP. ave. ° C	TEMP. max. ° C
5	42.40	2.5	3.9	4.9	4.7	5.3	5.9	21.0	23.8	28.0
8	60.70	2.6	5.5	7.6	1.5	5.9	7.4	15.2	18.5	23.7
10	63.80	4.1	5.8	8.5	2.8	5.0	6.0	15.2	18.6	23.8
11	66.30	2.1	3.7	6.1	6.1	7.2	8.0	14.5	17.8	23.2
12	68.60	3.1	4.3	5.8	5.8	6.5	7.3	14.7	17.8	23.2
13	71.43	3.8	11.2	22.0	5.2	5.6	6.1	14.5	17.7	22.2
14	75.0	2.8	5.3	6.5	6.9	7.5	8.2	15.1	17.7	21.0
15	78.03	2.8	4.8	7.4	8.1	9.1	9.7	15.6	18.4	21.0
L1*	63.80	2.5	4.9	6.7	5.5	7.2	8.4	15.5	18.7	24.0
L2	66.80	4.2	4.9	5.9	5.4	6.5	7.1	19.2	21.6	24.5
L3	71.20	4.6	6.5	8.5	6.6	7.4	7.9	20.7	23.0	24.5
L4	74.05	5.0	6.6	8.4	6.4	7.3	7.8	19.5	21.7	25.0
L6	77.2	4.1	5.0	6.4	7.3	7.4	7.6	20.4	22.0	25.0
L6A	Dorsey Run	4.9	14.0	21.0	3.0	3.9	5.3	20.3	22.0	24.3
L7	81.35	3.1	3.6	4.1	7.7	8.3	8.9	20.6	22.4	25.5
L8	85.2	1.8	3.7	6.2	7.0	7.7	8.4	19.4	21.0	23.5

* L Prefix denotes Little Patuxent River

TABLE 5

WATER QUALITY DATA FOR MONTHS OF
JULY, AUGUST, AND SEPTEMBER 1966

Patuxent River Basin

Station	River Mile	BOD min. mg/l	BOD ave. mg/l	BOD max. mg/l	DO min. mg/l	DO ave. mg/l	DO max. mg/l	TEMP. min. °C	TEMP. ave. °C	TEMP. max. °C
5	42.40	1.6	3.3	4.3	4.1	5.1	6.5	20.5	24.5	27.5
8	60.70	3.8	6.7	12.0	2.1	2.9	3.3	19.5	22.9	24.7
10	63.80	5.0	9.3	22.0	1.0	1.7	2.1	20.5	23.1	25.0
11	66.30	2.4	4.1	11.1	3.8	5.1	7.2	19.2	22.6	24.7
12	68.60	1.7	6.3	9.5	2.9	3.7	4.1	19.0	22.8	24.7
13	71.43	2.4	8.5	18	2.8	3.4	3.9	19.5	22.5	24.3
14	75.0	2.6	4.4	6.1	6.2	6.8	7.6	19.5	21.2	22.8
15	78.03	2.0	3.3	5.4	8.0	8.9	9.9	16.6	19.9	22.5
L1*	63.80	4.6	6.9	10.0	3.0	3.7	4.1	20.5	23.7	25.2
L2	66.80	6.8	7.6	9.1	3.8	4.5	4.8	21.2	22.1	24.0
L3	71.20	2.0	3.7	6.3	5.4	6.3	7.6	20.8	22.3	24.7
L4	74.05	1.4	4.6	6.2	3.6	4.5	5.3	20.7	22.7	25.0
L6	77.2	3.7	4.2	4.6	7.0	8.2	10.3	20.0	22.8	25.5
L6A	Dorsey Run	5.6	11.5	17.0	2.5	3.2	4.0	18.5	21.3	23.5
L7	81.35	2.1	3.1	3.7	8.3	9.1	10.0	18.5	24.2	28.0
L8	85.2	2.4	3.2	3.7	8.5	9.2	10.3	18.0	22.0	24.6

* L Prefix denotes Little Patuxent River

TABLE 6

PROJECTED INCREASE IN WASTE WATER VOLUMES
FOR MAJOR TREATMENT FACILITIES

Plant	Current		Projected	
	Flows mgd	Design Capacity mgd	Flows mgd	Per Cent Increase
Laurel Parkway (WSSC)	2.00	2.40	4.80	140
Bowie-Belair (Prince Georges County)	1.44	2.40	2.40	68
Savage (Howard County)	0.07	1.00	8.00	Major Expansion
Maryland City (Anne Arundel County)	0.44	0.75	1.30	195
Patuxent Plant (Anne Arundel County)	0.42	2.00	3.10	640
Western Branch (WSSC)	0.00	0.00	5.00	New Plant*
Fort Meade #1	1.11	2.50	2.50	126
Fort Meade #2	0.94	1.50	1.50	60

* Proposed plant will be discharging into Patuxent Estuary and not included in upstream calculations.

TABLE 7

MEAN MONTHLY AND DESIGN FLOWS*

For U.S.G.S. Gaging Station, Patuxent River Basin

Month	Little Patuxent at Guilford		Little Patuxent at Savage		Dorsey Run near Jessup		Patuxent Near Unity		Patuxent Near Laurel**		Western Branc near Largo	
	MEAN	DESIGN	MEAN	DESIGN	MEAN	DESIGN	MEAN	DESIGN	MEAN	DESIGN	MEAN	DESIG
January	43	16	103	37	12.5	3.5	3.5	12.5	130	54	28	8.9
February	53	25	120	51	19.5	10.0	47	22.0	180	63	41	16.8
March	60	32	140	65	27.5	12.5	54	28	177	95	53	26.0
April	54	21	128	55	18.5	6.5	46	19	162	82	43	15.7
May	39	18	105	39	11.7	3.5	38	15.5	132	64	24.0	6.1
June	28	14	88	35	9.4	2.9	28	10.2	104	48	16.0	4.0
July	21	7	63	19	6.4	1.9	20	4.3	70	23	10.0	1.7
August	18	6	54	14.5	7.6	1.9	13.0	5.0	76	19	12.0	1.0
September	17	4.6	47	12.5	6.4	2.0	15.0	5.1	54	13.2	9.2	1.0
October	20	7.0	46	15	6.9	1.9	13.5	5.8	62	17.0	9.0	2.6
November	28	10.0	74	25	9.7	2.5	23.0	9.8	72	22.5	19.0	6.2
December	34	14.0	88	33	18.0	4.0	30.0	10.2	88	43.0	24.0	8.0
7-Day 10-Year	4.4		12.0		1.9		4.1		9.2		1.3	

* Design flow is such a mean monthly low flow value in cfs, based on a log normal probability distribution, which occurs five per cent or less of the time.

** Does not include regulated flow values (formerly Burtonsville).

TABLE 8

MONTHLY VOLUME OF PATUXENT WATER FILTRATION PLANT
(Washington Suburban Sanitary Commission)

1966	Average Water Filtered (mgd)
January	28.76
February	30.26
March	29.76
April	29.91
May	48.91
June	55.12
July	58.46
August	48.75
September	50.75
October	43.87
November	42.85
December	42.65
Average	42.51

TABLE 9

POPULATION PROJECTIONS

Area	Per Cent in Basin	1960	1980	Per Cent Increase
Anne Arundel County	11	206,600	400,000	194
Calvert County	39	15,800	26,000	164
Charles County	6	32,600	52,000	160
Howard County	62	36,200	100,000	276
Montgomery County	2	340,900	551,000	162
Prince Georges County	18	357,400	745,000	208
St. Marys County	20	38,900	52,000	133
Baltimore Metropolitan Area		1,800,000	2,750,000	50
Washington, D. C. Metropolitan Area		2,050,000	3,550,000	73
Patuxent River Basin		135,000	270,000	200

TABLE 10

BASIC DATA FOR PATUXENT MODEL

Section	Lower Node	Upper Node	Distance (Miles)	Area (Sq.Mi.)	AA	BB	CC	DD
1	1	2	44.990	524.270	0.285	0.585	0.050	0.483
2	2	4	45.000	524.270	0.285	0.585	0.050	0.483
3	4	6	50.000	414.770	0.285	0.585	0.050	0.483
4	6	8	55.000	386.000	0.285	0.585	0.050	0.483
5	8	10	60.000	362.000	0.375	0.440	0.047	0.425
6	10	12	63.700	342.600	0.360	0.480	0.056	0.490
7	12	14	64.500	181.200	0.680	0.480	0.075	0.490
8	14	16	66.100	181.200	0.620	0.480	0.075	0.490
9	16	18	69.400	181.200	0.600	0.480	0.075	0.490
10	18	20	71.000	157.000	1.000	0.235	0.062	0.622
11	20	21	73.000	157.000	0.850	0.265	0.07	0.622
12	21	22	74.600	157.000	[illegible]	0.285	0.[illegible]	0.622
13	22	24	76.000	157.000	[illegible].660	0.285	0.[illegible]70	0.622
14	24	26	77.300	[illegible].000	0.660	0.285	[illegible].076	0.6[illegible]
15	26	28	78.[illegible]	133.000	0.660	0.285	0.080	0.[illegible]22
16	28	30	80.000	133.000	0.580	0.273	0.[illegible]	0.253
17	30	36	80.900	133.000	0.480	0.273	[illegible].[illegible]00	0.253
18	36	38	66.650	161.100	0.660	0.320	0.038	0.625
19	38	40	66.850	161.100	0.660	0.[illegible]20	0.039	0.625
20	[illegible]	[illegible]	70.650	140.000	0.550	[illegible].320	0.041	0.625
21	40	42	73.000	140.000	0.55[illegible]	0.320	0.042	0.625
22	42	46	75.450	125.000	[illegible].330	0.343	0.240	0.360
23	46	48	75.650	125.000	0.500	0.343	0.240	0.360
24	48	50	77.200	125.000	0.580	0.285	0.060	0.622
25	50	52	78.500	110.000	0.580	0.285	0.060	0.622
26	52	54	80.100	110.000	0.580	0.285	0.060	0.622
27	54	56	80.900	110.000	0.480	0.285	0.100	0.622
28	56	58	82.400	98.480	0.330	0.340	0.135	0.525

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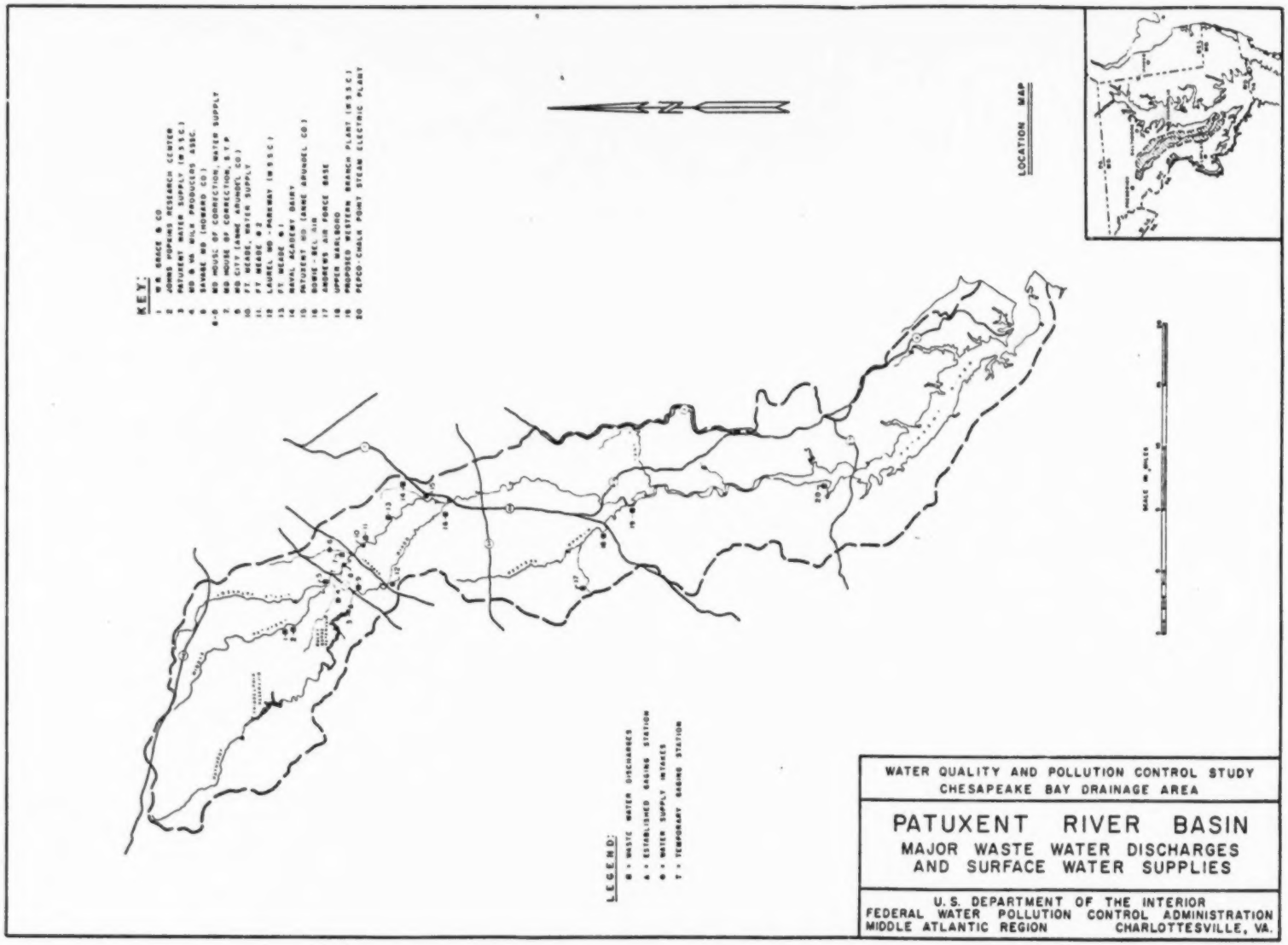
KEY:
1 W.R. GRACE & CO
2 JOHNS HOPKINS RESEARCH CENTER
3 PATUXENT WATER SUPPLY (WSSC)
4 MD & VA. MILK PRODUCERS ASSC.
5 SAVAGE MD (HOWARD CO.)
6-A MD HOUSE OF CORRECTION, WATER SUPPLY
7 MD HOUSE OF CORRECTION, STP
8 MD CITY (ANNE ARUNDEL CO.)
10 FT MEADE, WATER SUPPLY
11 FT MEADE #2
12 LAUREL MD.-PARKWAY (WSSC)
13 FT MEADE #1
14 NAVAL ACADEMY DAIRY
15 PATUXENT MD (ANNE ARUNDEL CO)
16 ANNE ARUNDEL CO.
17 ANDREWS AIR FORCE BASE
18 UPPER MARLBORO
19 PROPOSED WESTERN BRANCH PLANT (WSSC)
20 PEPCO-CHALK POINT STEAM ELECTRIC PLANT
LOCATION MAP
LEGEND:
W = WASTE WATER DISCHARGES
S = ESTABLISHED GAGING STATION
W = WATER SUPPLY INTAKES
T = TEMPORARY GAGING STATION
MILES

WATER QUALITY AND POLLUTION CONTROL STUDY
CHESAPEAKE BAY DRAINAGE AREA

PATUXENT RIVER BASIN

MAJOR WASTE WATER DISCHARGES AND SURFACE WATER SUPPLIES

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
MIDDLE ATLANTIC REGION CHARLOTTESVILLE, VA.

FIGURE 1

KEY:

1. W.R. GRACE & CO.
2. JOHNS HOPKINS RESEARCH CENTER
3. PATUXENT WATER SUPPLY (W.S.S.C.)
4. MD. & VA. MILK PRODUCERS ASSC.
5. SAVAGE MD. (HOWARD CO.)
6-8. MD. HOUSE OF CORRECTION, WATER SUPPLY
7. MD. HOUSE OF CORRECTION, S.T.P.
9. MD. CITY (ANNE ARUNDEL CO.)
10. FT. MEADE, WATER SUPPLY
11. FT. MEADE # 2
12. LAUREL MD. - PARKWAY (W.S.S.C.)
13. FT. MEADE # 1
14. NAVAL ACADEMY DAIRY
15. PATUXENT MD. (ANNE ARUNDEL CO.)
16. BOWIE - BEL AIR
17. ANDREWS AIR FORCE BASE
18. UPPER MARLBORO
19. PROPOSED WESTERN BRANCH PLANT (W.S.S.C.)
20. PEPCO - CHALK POINT STEAM ELECTRIC PLANT

LEGEND:

- ■ = WASTE WATER DISCHARGES
- ▲ = ESTABLISHED GAGING STATION
- ● = WATER SUPPLY INTAKES
- T = TEMPORARY GAGING STATION

N

LOCATION MAP

LEGEND:

■ = WASTE WATER DISCHARGES
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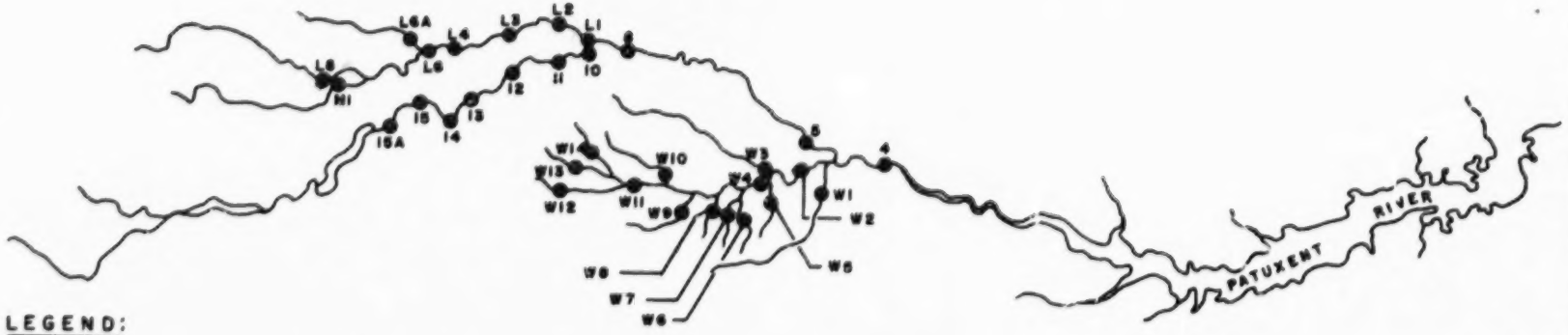
MAJOR WASTE WATER DISCHARGES AND SURFACE WATER SUPPLIES

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
MIDDLE ATLANTIC REGION CHARLOTTESVILLE, VA.

FIGURE 1



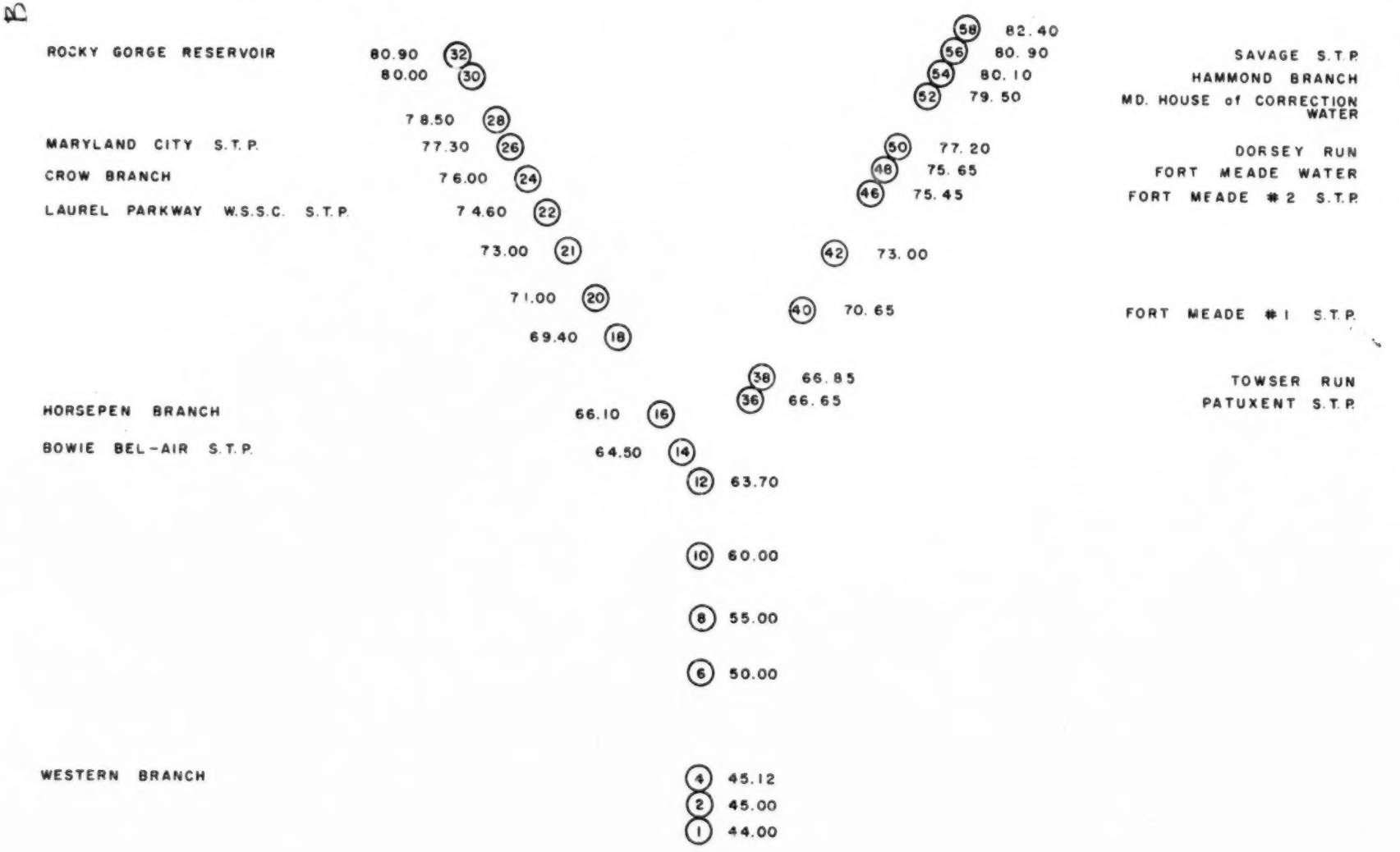
LEGEND:

NUMERALS	=	MAIN PATUXENT STATIONS
PREFIX L + NO.	=	LITTLE PATUXENT STATIONS
PREFIX M + NO.	=	MIDDLE PATUXENT STATIONS
PREFIX W + NO	=	WESTERN BRANCH STATIONS

● = SAMPLING STATIONS AND DESIGNATIONS DEPT. OF WATER RESOURCES, STATE OF MD.

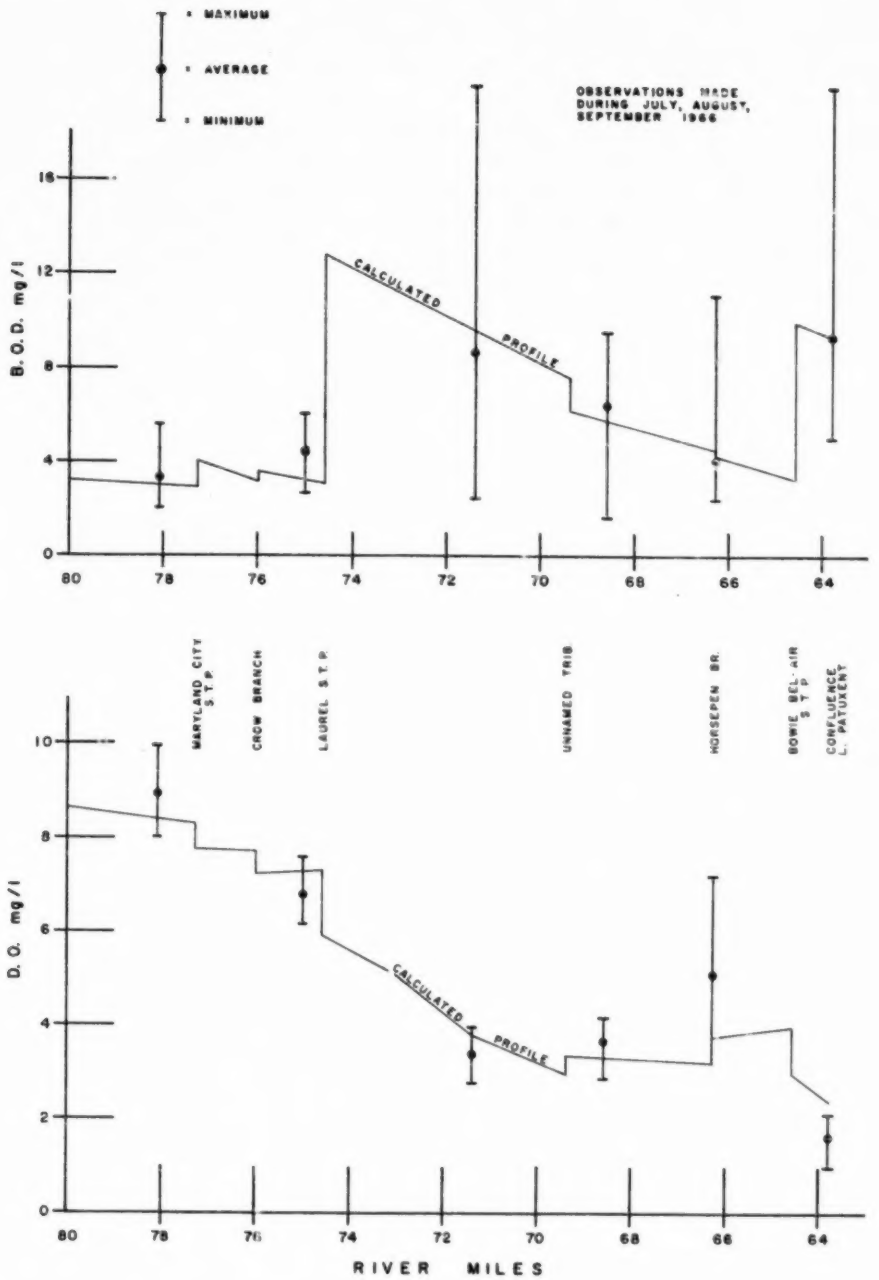
PATUXENT RIVER BASIN

WATER QUALITY SURVEY MAP



PATUXENT RIVER BASIN

SCHEMATIC - PATUXENT RIVER BASIN MODEL



PATUXENT RIVER BASIN

B.O.D. & D.O. PROFILE

ROCKY GORGE to LITTLE PATUXENT CONFLUENCE